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IMAGE PREDICTIVE CODING METHOD

VERIFICATION OF ENGLISH TRANSLATION

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Sir:

I, Kazuhiko YASUI of c/o Aoyama & Partners, IMP Building, 1-3-7, Shiromi, Chuo-ku, Osaka 540-0001 Japan, declare that I am conversant in both the Japanese and English languages and that the English translation as attached hereto is an accurate translation of Japanese Patent Application No. P8-254677 filed on September 26, 1996.

February 12, 2008

Kazuhiko YASUI

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This is to certify that the annexed is a true copy of the following application as filed with this Office.

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Title of the Invention:

DC/AC PREDICTION METHOD BY ADAPTIVE COEFFICIENT SCAN

Claims:

1. A method for improving image coding efficiency by an adaptive prediction technique in a transform domain, including the following steps of:

sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array;

transforming the pixels of the sampled blocks into a transform domain;

forming prediction blocks for coefficients of the blocks by using information from blocks which have previously been reconstructed and stored in a block memory;

making a decision on the most efficient prediction block and a scan method to be used, and transmitting this decision to a decoder in a form of prediction mode;

subtracting the selected prediction block from the current block, thereby forming a prediction error signal based on the decision;

quantizing the prediction error signal;

scanning the block of the quantized prediction error signal in a sequence of events;

coding the sequence of events in an entropy coding manner and transmitting the coded information to the decoder;

inverse quantizing the quantized prediction error signal;

adding the coefficients of the current block to the prediction error signal obtained by inverse quantizing the prediction block, thereby forming a block of reconstructed coefficients;

storing the block of the reconstructed coefficients into a block memory for prediction; and

subjecting the block of the coefficients to an inverse transform process, thereby obtaining a block of a reconstructed pixel domain.

2. A method for improving image coding efficiency by an adaptive prediction technique in a transform domain, including the following steps of:

sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array;

transforming the pixels of the sampled blocks into a transform domain;

forming prediction blocks for coefficients of the blocks by using information from blocks which have previously been reconstructed and stored in a block memory;

making a decision on the most efficient

prediction block and a scan method to be used, and transmitting this decision to a decoder in a form of prediction mode;

subtracting the selected prediction block from the current block, thereby forming a prediction error signal based on the decision;

scanning the block of the prediction error signal in a sequence of events;

coding the sequence of events in an entropy coding manner and transmitting the coded information to the decoder;

reconstructing the current block of quantized coefficients by adding the same prediction block to the prediction error signal, thereby forming a reconstructed block of quantized coefficients;

storing the quantized reconstruction block into a block memory for prediction;

inverse quantizing the quantized coefficients; and

subjecting the coefficient block to an inverse transform process to obtain a block of a reconstructed pixel domain.

3. A DC/AC prediction method by adaptive coefficient scan, including the following steps of:

sampling an inputted image into a plurality of

blocks each including pixels of a two-dimensional array;

processing the pixels of the blocks by a motion compensation step, thereby obtaining a block of a motion-compensated prediction error signal;

transforming the block of the motion-compensated prediction error signal into a transform domain;

forming prediction blocks for the blocks of transformed coefficients by using information from blocks which have previously been reconstructed and stored in a block memory;

making a decision on the most efficient prediction block and a scan method to be used, and transmitting this decision to a decoder in a form of prediction mode;

subtracting the selected prediction block from the current block, thereby forming a prediction error signal based on the decision;

quantizing the prediction error signal;

scanning the block of the quantized error signal in a sequence of events;

coding the sequence of events in an entropy coding manner and transmitting the coded information to the decoder;

inverse quantizing the quantized prediction error signal;

reconstructing the current block by adding the prediction block to the quantized prediction error signal, thereby forming a block of reconstructed coefficients;

storing the block of the reconstructed coefficients into a block memory for the next prediction;

subjecting the coefficient block to an inverse transform process to reproduce the prediction error with the pixel domain motion-compensated; and

adding the motion-compensated prediction to the motion-compensated prediction error signal, thereby obtaining a block of reconstructed pixels.

4. A method for improving image coding efficiency by an adaptive prediction technique in a transform domain, including the following steps of:

sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array;

processing the pixels of the blocks by a motion compensation step, thereby making a block of a motion-compensated prediction error signal;

quantizing coefficients of the transform domain;

forming prediction blocks for the blocks of transformed coefficients by using information from blocks which have previously been reconstructed and stored in a block memory;

making a decision on the most efficient

prediction block and a scan method to be used, and transmitting this decision to a decoder in a form of prediction mode;

subtracting the selected prediction block from the current block, thereby forming a prediction error signal based on the decision;

scanning the block of the quantized prediction error signal in a sequence of events;

coding the sequence of events in an entropy coding manner and transmitting the coded information to the decoder;

reconstructing the current block by adding the prediction block to the quantized prediction error signal, thereby forming a block of reconstructed coefficients;

storing the block of the reconstructed coefficients into a block memory for the next prediction;

inverse quantizing the quantized coefficients;

inverse transforming the inverse quantized coefficients, thereby making a reconstructed pixel-domain motion-compensated prediction error signal; and

adding the motion-compensated prediction to the motion-compensated prediction error signal, thereby obtaining a block of reconstructed pixels.

5. A method for improving image coding efficiency by an adaptive prediction technique in a

transform domain, including the following steps of:

extracting information relating to prediction and scan method from a prediction mode shown in a bit stream;

coding the bit stream in an inverse entropy coding manner to obtain a sequence of decoded events;

inverse scanning the decoded events in a block of quantized prediction error according to the scan method;

inverse quantizing the quantized prediction error;

making a prediction block for the block of coefficients transformed based on the prediction mode, and using information from a block which has previously been reconstructed and stored in the block memory;

reconstructing the current block of the coefficients by adding the prediction block to the inverse quantized prediction error, thereby forming a block of reconstructed coefficients;

storing the block of the reconstructed coefficients into the block memory for the next prediction;

inverse transforming the inverse quantized coefficients, thereby making a reconstructed pixel domain block; and

reconstructing the decoded image by coupling the reconstructed blocks.

6. The DC/AC prediction method by adaptive

coefficient scan as claimed in Claim 2,

wherein the decoder performs the following steps of:

extracting information relating to prediction and scan method from a prediction mode shown in a bit stream;

coding the bit stream in an inverse entropy coding manner to obtain a sequence of decoded events;

inverse scanning the decoded events in a quantized prediction error of the block according to the scan method;

making a prediction block for the block of coefficients quantized and transformed based on the prediction mode, and using information from a block which has previously been reconstructed and stored in the block memory;

reconstructing the current block of the quantized coefficients by adding the prediction block to the quantized prediction error, thereby forming a block of reconstructed quantized coefficients;

storing the quantized coefficients of the reconstructed block into the block memory for the next prediction;

inverse quantizing the quantized coefficients;

inverse transforming the inverse quantized coefficients, thereby obtaining a reconstructed pixel

domain block; and

reconstructing the decoded image by coupling the reconstructed blocks.

7. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 3,

wherein the decoder performs the following steps of:

extracting information relating to prediction and scan method from a prediction mode shown in a bit stream;

coding the bit stream in an inverse entropy coding manner to obtain a sequence of decoded events;

inverse scanning the decoded events in a quantized prediction error of the block according to the scan method;

inverse quantizing the quantized prediction error;

forming a prediction block for the block of the coefficients transformed based on the prediction mode, and using information from a block which has previously been reconstructed and stored in the block memory;

reconstructing coefficients of the current block by adding the prediction block to the inverse quantized prediction error, thereby forming a block of reconstructed coefficients;

storing the block of the reconstructed

coefficients into the block memory for the next prediction;

inverse transforming the coefficients of the block to reproduce a pixel domain motion-compensated prediction error;

obtaining a block of reconstructed pixels by adding the motion-compensated prediction to the reproduced motion-compensated prediction error signal; and

reconstructing the decoded image by coupling the reconstructed blocks.

8. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 4,

wherein the decoder performs the following steps of:

extracting information relating to prediction and scan method from a prediction mode shown in a bit stream;

coding the bit stream in an inverse entropy coding manner to obtain a sequence of decoded events;

inverse scanning the decoded events in a quantized prediction error of the block according to the scan method;

forming a prediction block for the quantized prediction coefficients of the block based on the prediction mode, and using information from a block which has previously been reconstructed and stored in the block memory;

reconstructing the current block of the quantized coefficients by adding the prediction block to the quantized prediction error, thereby forming a block of reconstructed quantized coefficients;

storing the quantized coefficients of the reconstructed block into the block memory for the next prediction;

inverse quantizing the quantized coefficients;

inverse transforming the inverse quantized coefficients to make a reconstructed pixel domain motion-compensated prediction error;

obtaining a reconstructed pixels of the block by adding the motion-compensated prediction to the reproduced motion-compensated prediction error signal; and

reconstructing the decoded image by coupling the reconstructed blocks.

9. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3 or 4,

wherein the step of scanning the inputted image in a plurality of blocks including the pixels of a two-dimensional arrangement, further includes an interleave process for inserting pixels so that the pixels in a two-dimensional array in a group of four blocks are comprised of odd-numbered pixels located in odd-numbered rows in a first block, the pixels thereof are comprised of even-

numbered pixels located in the odd-numbered rows in a second block, the pixels thereof are comprised of odd-numbered pixels located in even-numbered rows in a third block, and the pixels thereof are comprised of even-numbered pixels located in the even-numbered rows in a fourth block.

10. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from blocks which have been previously restored, stored in the block memory and located adjacently to the current block under the coding process, and all coefficient data in the block are selected.

11. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from blocks which have been previously restored, stored in the block memory and located adjacently to the current block under the coding process, and predetermined subset and coefficients of each block are selected.

12. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from blocks located upwardly or leftwardly adjacent to the current block under the coding process, only the coefficient data of the top row of the block and the leftmost column of the block are used and the remaining coefficient data are set to zero.

13. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 2, 4, 6 or 8,

wherein the prediction block is selected from the blocks which have been previously restored and stored in the block memory according to the standard of Claim 12, and use of only a subset including one or more pieces of coefficient data from the top row or the leftmost column of the block is determined by conventional communications between the encoder and the decoder.

14. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 2, 4, 6 or 8,

wherein the prediction block is selected from the blocks which have been previously restored and stored in the block memory according to the standard of Claim 12, use of only a subset including one or more pieces of coefficient data from the top row or the leftmost column of the block is determined by the encoder, and the decoder is informed of a flag which indicates the determined subset and the number of pieces of coefficient data by

periodically inserting the flag into data transmitted to the decoder.

15. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 2, 4, 6 or 8,

wherein the prediction block is selected from the blocks which have been previously restored and stored in the block memory according to the standard of Claim 9, 10, 11 or 11, and the coefficient data of each block is multiplied by a ratio equal to a ratio of a quantization step size of the current block to be coded to a quantization step size of the prediction block.

16. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from the blocks which have been previously restored and stored in the block memory according to the standard of Claim 9, 10, 11 or 12, and the coefficient data of each block is weighted by different weighting factor.

17. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from the blocks which have been previously restored and stored in the block memory according to the standard of Claim 9, 10,

11 or 12, and the coefficient data of each block is subjected to a specified transform computation.

18. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is obtained through weighted averaging of the blocks which have been previously restored and stored into the block memory and located adjacently to the current block under the coding process.

19. The DC/AC prediction method by adaptive coefficient scan according to the method of scanning the coefficients of blocks as described in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the scan method includes at least one scan method of the followings:

a horizontal scan executed so that the coefficient data are scanned every row from left to right, started from a top row and ended in the bottom row;

a vertical scan executed so that the coefficient data are scanned every column from the top row toward the bottom row, started from a leftmost column and ended in a rightmost column; and

a zigzag scan executed so that the coefficient data are diagonally scanned from the leftmost coefficient data in the top row toward the rightmost coefficient data

in the bottom row.

20. The DC/AC prediction method by adaptive coefficient scan according to the method for improving image coding efficiency by an adaptive prediction technique in a transform domain as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from the blocks which have been previously restored and stored in the block memory according to the standard of Claim 12, and

wherein one of the following four prediction modes is activated:

a first mode in which only the top and leftmost coefficient data representing an average value of a block called a DC coefficient from a block located on the upper side of the target current block to be processed are used for prediction;

a second mode in which only a DC coefficient from a block located on the left-hand side of the target current block to be processed is used for prediction;

a third mode in which a DC coefficient and zero or more AC coefficients including a high-frequency component from a top row of the block located on the upper side of the target current block to be processed are used for prediction; and

a fourth mode in which a DC coefficient and zero

or more AC coefficients including a high-frequency component from a leftmost column of a block located on the left-hand side of the target current block to be processed are used for prediction, and

the coefficient data of the prediction error is scanned according to the zigzag scan method.

21. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from the blocks which have been previously restored and stored in the block memory according to the standard of Claim 12, the coefficient data of the prediction error is scanned according to one of the scan methods claimed in Claim 18, and one of the following four prediction modes is activated:

a first mode in which only a DC coefficient of a block located on the upper side of the target current block to be processed is used for prediction and the coefficient data of the prediction error is subjected to the zigzag scan process;

a second mode in which only a DC coefficient of a block located on the left-hand side of the target current block to be processed is used for prediction and the coefficient data of the prediction error is subjected to

the zigzag scan process;

a third mode in which a DC coefficient and zero or more AC coefficients including a high-frequency component of a top row of a block located on the upper side of the target current block to be processed are used for prediction and the coefficient data of the prediction error is subjected to the horizontal scan process;

a fourth mode in which a DC coefficient and zero or more AC coefficients including a high-frequency component of a leftmost column of a block located on the left-hand side of the target current block to be processed are used for prediction and the coefficient data of the prediction error is subjected to the vertical scan process.

22. The DC/AC prediction method by adaptive coefficient scan according to the method for improving image coding efficiency by an adaptive prediction technique in a transform domain as claimed in Claim 1, 2, 3 or 4,

wherein the method of determining the highest efficient prediction block to be used includes the following steps of:

scanning a different prediction error block in a sequence of run level events;

coding the events by an entropy containing method;

ensuring all bits used in a different prediction

block;

comparing bits to be used in a different prediction error block; and

selecting a prediction block corresponding to the prediction error block and resultantly using lower order bits.

23. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the method of storing and reconstructing the decoded image from a plurality of interleaved four blocks in the two-dimensional array of pixels further includes a deinterleaving process of:

obtaining all of odd-numbered pixels located in odd-numbered rows from a first block;

obtaining even-numbered pixels located in the odd-numbered rows from a second block;

obtaining odd-numbered pixels located in even-numbered rows from a third block;

obtaining even-numbered pixels located in the even-numbered rows from a fourth block.

24. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein discrete cosine transform is used as the

transform method.

25. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction mode is not transmitted from the encoder for the bit stream to the decoder, but the same rules as in determining the prediction type can be used by the encoder and the decoder, and both the encoder and the decoder use the rules for determining the prediction mode.

26. The DC/AC prediction method by adaptive coefficient scan as claimed in Claim 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the scan pattern is not specified in a flag transmitted from the encoder to the decoder in the bit stream, but the same rules as in determining the scan pattern can be used by the encoder and the decoder, and both the encoder and the decoder use the rules for determining the scan pattern to be used.

Detailed Description of the Invention:

[0001]

Field of the Invention:

The present invention can be used for the coding of static image coding and motion image coding and, in particular, for the coding in block transform based on

image coding.

[0002]

Prior Art:

The image coding has been widely used in many international standards such as JPEG, MPEG1, H.261, MPEG2 and H.263. Each of the latter standards has a more improved coding efficiency. That is, there has been a demand for reducing the number of bits as compared with the conventional standards in expressing the same image quality.

[0003]

Image coding of a dynamic image is comprised of a coding between frames and a coding between predicted frames. In a representative hybrid coding system such as MPEG1 Standard, frames in a sequence can be classified into three different types: intra-frame (I-frame), prediction frame (P-frame) and two-dimensional prediction frame (B-frame). The I-frame is coded independently of the other frames, i.e., the I-frame is compressed without using the other frames. The P-frame is coded through motion prediction and compensation by using the immediately preceding frame for the purpose of predicting the contents of a coded frame (P-frame). The preceding frame is either an I-frame or a P-frame. The B-frame is coded through motion prediction and compensation by using information

from the immediately preceding frame and information from the subsequent frame for predicting the contents of the B-frame. The preceding frame and the subsequent frame are the I-frame or the P-frame. The I-frame belongs to the intra-coding mode. The P-frame and the B-frame belong to the prediction coding mode.

[0004]

Since the blocks are based on the execution of the discrete cosine transform (DCT), the current image coding methods are all based on the division of an image into smaller blocks. According to the intra-frame coding, an inputted digital image is first subjected to a block sampling process as shown in Fig. 1. Next, these blocks are subjected to a DCT transform process, and subjected to a quantizing process and a run length Huffman variable length coding (VLC) process. According to the prediction frame coding, an inputted digital image is subjected first to a motion compensating process, and the motion-compensated block (i.e., the predicted block) is subjected to the DCT transform process. Next, the quantizing process and the run length Huffman VLC coding process are executed.

[0005]

As apparent in the image coding technique of the present time, the block-based DCT transform process removes or reduces a redundancy inside the block. The motion

detecting and compensating processes remove or reduce a temporary redundancy between adjacent frames. The run length Huffman VLC coding or another entropy coding process executed after the DCT transform process and the quantizing process removes a statistical redundancy between quantized DCT transform coefficients. However, redundancy still remains in the block.

[0006]

A digital image inherently includes a great spatial redundancy. This redundancy exists not only inside a block but also between blocks over blocks of an image. Therefore, as is apparent from the above facts, no existing method uses the process for removing the redundancy between blocks of one image at all except for the DC coefficient prediction of JPEG, MPEG1 and MPEG2.

[0007]

According to MPEG1 and MPEG2, the DC coefficient prediction is executed by subtracting the DC value of the preceding coded block from the currently coded block. This is a simple predicting method which does not have an adaptiveness or mode switching when the prediction is inappropriate. Further, it merely includes DC coefficient.

According to the current state of the concerned technical field, the zigzag scan is used for all blocks prior to the run length coding. No attempt at making scan

adaptive on the basis of the contents of the block has been made.

[0008]

Fig. 1 shows a block diagram of an encoder. The prior art comprises a block sampling module 1, a DCT transform module 3, a quantizing module 4, a zigzag scan module 5 and an entropy coding module 6.

[0009]

According to the intra-frame coding, an inputted image is subjected to a block sampling process and thereafter subjected directly to a DCT transform process. Then, a quantizing process, a zigzag scan process and an entropy coding process are sequentially executed. On the other hand, according to the inter-frame coding (prediction frame coding), a motion detecting and compensating process is executed in a module 11 after the block sampling process, and then a prediction error is obtained in a module 2. This prediction error is subjected to the DCT transform process and then to the quantizing process, zigzag scan process and entropy coding process similar to the intra-frame coding.

In a local decoder, a inverse quantizing process and an inverse DCT transform process are executed in modules 7 and 8. According to the intra-frame coding, a prediction value obtained through motion detection and

compensation is added to the reconstructed prediction error to make a local decoder image in a module 9. The local decoder image is stored into a frame memory module 10 of the local decoder.

[0010]

Finally, a bit stream is outputted from the entropy coding module 10 and transmitted to the decided. Fig. 2 is an explanatory view of a prior art decoder. The bit stream is decoded in a variable length decoder module 21, and the decoded data is then subjected to a inverse quantizing process and an inverse DCT transform process in modules 23 and 24. According to the inter-frame coding, a motion-compensated prediction formed by a unit 27 is added to the reconstructed prediction error, by which a locally decoded image is formed by a module 25. The locally decoded image is stored into a frame memory module 26 of the local decoder.

[0011]

Accordingly, from the point of view of the image coding efficiency, we can expect further improvement in redundancy by reducing not only the redundancy between two images or the inside of a block in one image but also the redundancy between the blocks in an image and by making the block scan pattern more appropriate.

[0012]

Problems to be Solved by the Invention:

According to the existing image coding techniques, the DCT transform process or other transform process is executed on the block basis due to the restrictive conditions in terms of hardware formation and calculation.

The spatial redundancy would be reduced through the block-based transform. However, it is restricted to the inside of a block. The redundancy between adjacent blocks is not satisfactorily considered. In particular, the intra-frame coding which consistently consumes a great amount of bits is not satisfactorily considered.

[0013]

An object of publishing the present invention is therefore to solve the insufficiency of the prior art coding. The issue to be resolved is how the redundancy in a block is removed by introducing an adaptive prediction into a transform domain.

At the same time, the important transform coefficients are concentrated on different regions of a block depending on the internal properties of the image. A second object to be solved by publishing the present invention is to improve in the efficiency of entropy coding by discriminating a proper scan method for blocks.

[0014]

Means for Solving the Problems:

It has been discovered that DCT transform coefficients in adjacent blocks closely resemble one another in many cases even when located in the same positions. In a case where the properties of two blocks of the original image closely resemble each other, or when they include same horizontal or vertical line, diagonal line or another image pattern, the aforementioned fact can be considered correct. From the viewpoint of information theory, identical information means a redundancy.

[0015]

The redundancy existing in the DCT transform domain over a block can be removed or reduced by adaptive prediction of the preceding block. This fact produces the result that the VLC entropy coding can achieve a higher coding efficiency for the smaller entropy of a prediction error signal.

At the same time, it has been well known that important DCT transform coefficients are concentrated on the transform blocks located in the leftmost column and the top row in the horizontal and vertical structures. Therefore, the present invention can solve the issue of the coefficient scan by making scan adapted based on a prediction mode.

[0016]

The present invention presents an attempt for adaptively predicting the DCT transform coefficients of the current block from another block, consequently removing the redundancy between adjacent blocks. Prediction error information can be further reduced by making a scan method adapted to the prediction mode in which the entropy of the quantization DCT transform coefficients is made smaller. As a result, the number of bits for coding the DCT transform coefficients can be reduced.

In an attempt at solving this problem, a method for executing the determination of the prediction mode is obtained on the basis of the actual bit rate generated by each prediction and scan method.

[0017]

The present invention provides a method for predicting the DCT transform coefficients of the current block. The DCT transform tends to give an identical value or an identical DCT transform coefficients distribution to an identical block, and therefore, the current block normally keeps a satisfactory mutual relationship with the DCT transform coefficients in the other adjacent blocks.

An inputted image is of an intra-frame or temporarily predicted frame. First, the inputted image is subjected to a DCT transform process which is normally based on a block. After the DCT transform coefficients of

the current block are obtained, the prediction of the DCT transform domain can be executed before or after quantization.

[0018]

The DCT transform coefficients in the current block can be predicted from the preceding adjacent block located diagonally on the upper left-hand side. They have already been decoded at the time as shown in Fig. 2. A predicted block is obtained by subtracting one or more DCT transform coefficients of the preceding adjacent block from the DCT transform coefficients in the same position of the current block forming a prediction error signal.

A prediction error signal from a different prediction mode is quantized if a prediction is made before the quantizing process. The quantized prediction error is scanned for a sequence of events before entropy coding is executed. A block predicted on the basis of the least bit use is selected. An expression of the coded block is transmitted to a decoder together with the prediction mode.

[0019]

The decoder decodes the predicted block by means of the prediction mode and the coded expression of the block. After the coded expression of the block is subjected to inverse entropy decoding, the quantized prediction error is inverse scanned according to a scan

mode to be used. If the quantizing process is executed after the predicting process, the block is inverse quantized. The reconstructed block can be obtained by adding the DCT transform coefficients into the previously decoded adjacent block designated by the prediction mode to the current DCT transform coefficients. When the quantizing process is executed before the predicting process, the reconstructed coefficients are inverse quantized. Finally, the inverse DCT transform process is applied to the DCT transform coefficients reconstructed for each block, so that a decoded image can be obtained.

[0020]

Embodiments of the Invention:

The present invention provides an image coding method which reduces the redundancy existing in the DCT transform domain over the adjacent block.

[0021]

Fig. 3 shows a block diagram of an encoder according to an embodiment of the present invention. Shaded modules are additions to the existing prior art and form the present invention. According to the intra-frame coding, an inputted image is subjected to a block sampling 31 and thereafter subjected directly to a DCT transform process. Subsequently, quantizing processes are executed by modules 33 and 34. According to the inter-frame coding

or inter-frame coding (prediction frame coding), after a block sampling process, a motion prediction and compensation process is executed at a module 45. Then, a prediction error is obtained by a module 32. This prediction error is subjected to the DCT transform and subsequently to the quantization. The DCT transform coefficients are predicted in a DCT transform domain process of a module 40, and a prediction error is obtained by a module 35. The predict error signal is subjected to a horizontal, vertical or zigzag scan adaptively in an H/V/Z scan module 36, depending on the selected prediction mode. The scanned event is VLC coded in a module 37 and a bit stream is transmitted to the decoder.

[0022]

In the local decoder, the prediction error is stored again into a module 38, and stored in a block memory 39 to be used for the next prediction. An inverse quantizing process and an inverse DCT transform process are executed in modules 41 and 42, respectively. According to the inter-frame coding, in order to generate a locally decoded image, a motion-compensated prediction is added to the reconstructed prediction difference at the module 43. The locally decoded image is stored into a frame memory module 44 of the local decoder.

[0023]

Finally, a bit stream is outputted from the entropy coding module and transmitted to the decoder. Fig. 4 is a block diagram for explaining the decoder according to the present embodiment. Shaded modules are new modules for completing the present invention. A bit stream is decoded in a variable length decoder module 51. The decoded event is scanned horizontally in the reverse direction, vertically in the reverse direction or in a zigzag manner in the reverse direction in a module 52. The prediction formed by a module 55 is added to a reversely scanned block in a module 53, by which the prediction error is reproduced. At the same time, the decoded DCT transform coefficients are stored into a block memory 54. Inverse quantizing and inverse DCT transform coefficients are stored in a block memory module 54. The inverse quantizing process and the inverse DCT transform process are executed in modules 56 and 57, respectively. According to the inter-frame coding, motion-compensated prediction is formed in a module 60, added to the prediction error reconstructed in a module 58, by which a locally decoded image is formed. The locally decoded image is stored into a locally decoding frame memory module 59.

[0024]

Fig. 5 is an explanatory view of the construction of a macro block and blocks derived from the sharing of

blocks. An inserting operation shows how the prediction process encodes the current block. A block C(u,v) is derived from an upwardly adjacent block A(u,v) and moves to a leftwardly adjacent block B(u,v).

A possible embodiment for explaining the present invention in more detail is described next.

[0025]

1. Coefficient number used for prediction

The coefficient number used for prediction depends on the sequence of image data. A flag AC_Coeff is used for adaptively selecting the optimum number of coefficients to be used for each image. The flag is shown in the following table and transmitted as part of side information to a decoder.

Table 1:

Table 1: Fixed Length Code FLC for Flag AC_Coeff

Index	AC_Coeff (used for Prediction)	FLC
0	DC only	000
1	DC + AC1	001
2	DC + AC1 + AC2	010
3	DC + AC1 + AC2 + AC3	011
4	DC + AC1 + AC2 + AC3 + AC4	100
5	DC + AC1 + AC2 + AC3 + AC4 + AC5	101
6	DC + AC1 + AC2 + AC3 + AC4 + AC5 + AC6	110
7	DC + AC1 + AC2 + AC3 + AC4 + AC5 + AC6 + AC7	111

In this case, ACn is A(0,n) or B(n,0) depending on the mode to be used.

[0026]

2. Scaling of Q-step

It is noticeable that when an adjacent block is quantized with a quantization step size different from that of the current block, the prediction of AC coefficients is not so efficient. Prediction is corrected so that the predicting operation is scaled according to the ratio of

the quantization step size of the current block at the present time point to the quantization step size of the prediction data block. This definition is given in the following section of explanation.

[0027]

3. Prediction mode

The modes are as follows.

Mode 0: DC prediction from the block located on the upper side

$E_0(0,0) = C(0,0) - A(0,0)$, and other ways

$E_0(u,v) = C(u,v)$ ....(1)

Mode 1: DC prediction from the block located on the left-hand side

$E_1(0,0) = C(0,0) - B(0,0)$, and other ways

$E_1(u,v) = C(u,v)$ ....(2)

Mode 2: DC/AC prediction from the block located on the upper side

$E_2(0,0) = C(0,0) - A(0,0)$,

$E_2(0,v) = C(0,v) - A(0,v)*Q_A/Q_C$,

$v = 1, \ldots,$ AC_Coeff, and other ways

$E_2(u,v) = C(u,v)$ ....(3)

Mode 3: DC/AC prediction from the block located on the left-hand side

$E_3(0,0) = C(0,0) - B(0,0)$,

$E_3(u,0) = C(u,0) - B(u,0)*Q_B/Q_C$

u = 1, ..., AC_Coeff, and other ways

$E_3(u,v) = C(u,v)$ ....(4)

[0028]

4. Adaptive horizontal/vertical/zigzag scan

If the above four prediction modes are given, the efficiency of the intra-frame coding can be further improved by adopting a coefficient scan. Fig. 6 show different scans in use. These scans are collectively referred to as H/V/Z scans.

[0029]

5. Determination of mode

Fig. 7 shows a mode determining process. DCT transform coefficient data of the current block is inputted to a module 62, and the module 62 subtracts the inputted DCT transform coefficient data of the current block from the DCT transform coefficient data of the adjacent block obtained from a block memory module 61, thereby executing a DCT transform predicting process. The DCT transform predicting process is executed in the four modes described in the section 3. Then, the coefficient scan process is executed in an H/V/Z scan module 63, and in this case, the respectively corresponding scan processes described in the section 4 are executed. Scanned events are transmitted to an entropy coding module 64 in which the variable length coding process is executed. Then, all the bits generated

are compared with one another by a module 65, where the module which generates the least amount of bits. These bits are outputted as a bit stream by the module 66 together with the prediction mode.

[0030]

The value of the prediction is transmitted to the decoder as a bit stream. The prediction mode is coded with the fixed length codes shown in Table 2.

Table 2:

Table 2: FLC Table for DC/AC/SCAN Mode

Index	DC/AC Mode	Scan Mode	FLC code
0	Upward DC	Zigzag Scan	00
1	Leftward DC	Zigzag Scan	01
2	Upward (DC + AC)	Horizontal Scan	10
3	Leftward (DC + AC)	Vertical Scan	11

[0031]

Effects of the Invention:

The present invention is very effective in reducing or removing the redundancy in the DCT transform domain over the adjacent block, and the total number of bits to be used is reduced, consequently allowing the

coding efficiency to be remarkably improved. This is also useful as a tool of a novel image compression algorithm.

Brief Description of the Drawings:

Fig. 1 is a block diagram of an encoder according to the prior art;

Fig. 2 is a block diagram of a decoder according to the prior art;

Fig. 3 is a block diagram of an encoder according to an embodiment of the present invention;

Fig. 4 is a block diagram of a decoder according to an embodiment of the present invention;

Fig. 5 is a schematic view showing the constructions of a macro block and blocks of a frame as well as a block predicting method;

Fig. 6 is a schematic view for explaining the horizontal, vertical and zigzag scan sequence to be used for a coefficient scan; and

Fig. 7 is a schematic view for explaining a mode determining process used in an embodiment of the present invention.

Reference Numerals:

1 block sampling

5 zigzag scan

6 VLC ... bit stream

7 inverse quantization

8 inverse DCT

10 frame memory

11 motion detection and compensation

22 inverse zigzag scan

26 frame memory

27 motion compensation

36 H/V/Z scan

40 DCT transform domain prediction by quantizing scan

55 prediction of DCT transform domain

62 subtract DCT transform coefficients from adjacent DCT transform block

65 comparison of bits used for different prediction blocks

66 output and encode a prediction block with use of lower order bit. Output of prediction mode.

Document Name: Drawings

Fig. 1

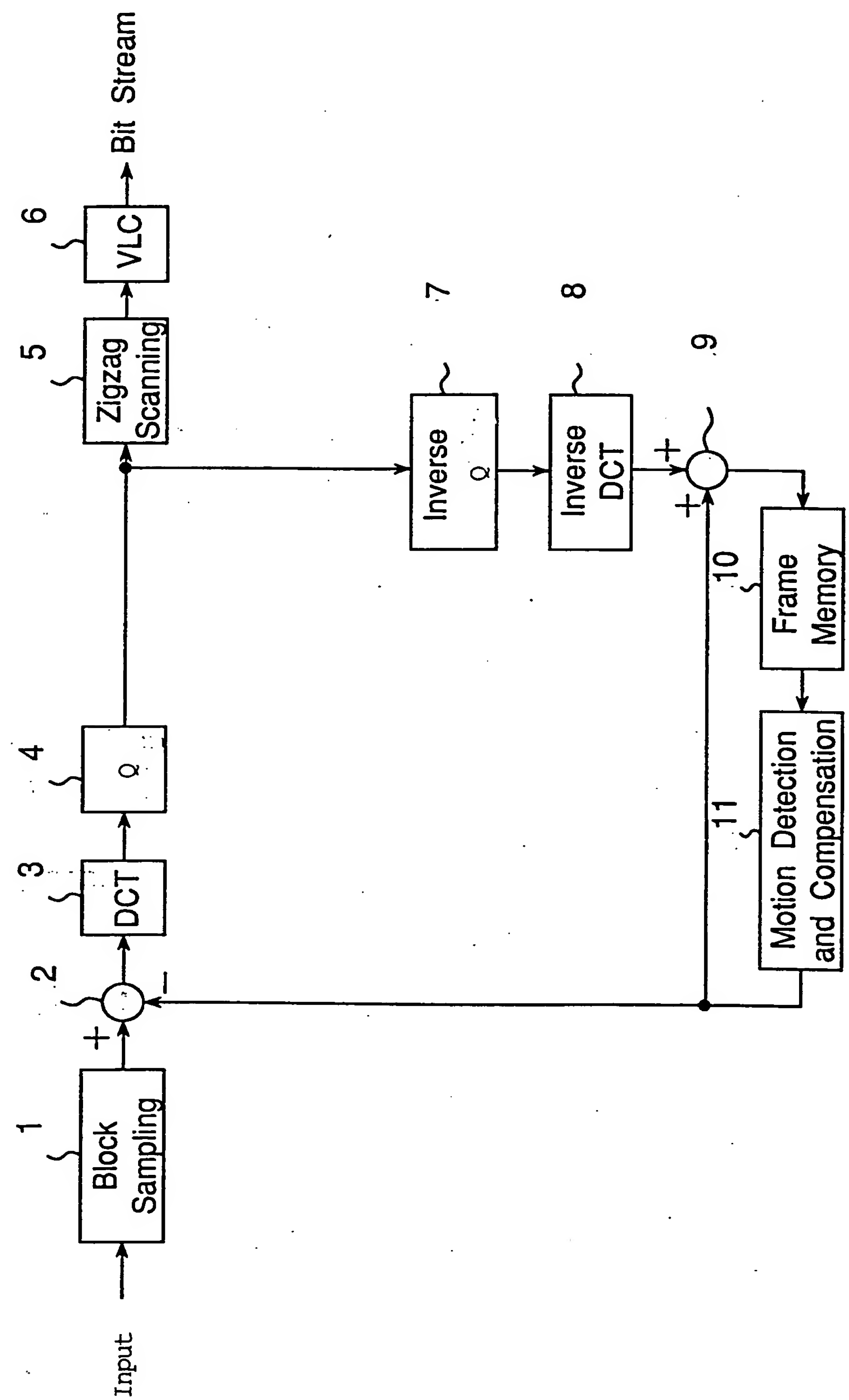


Fig. 2

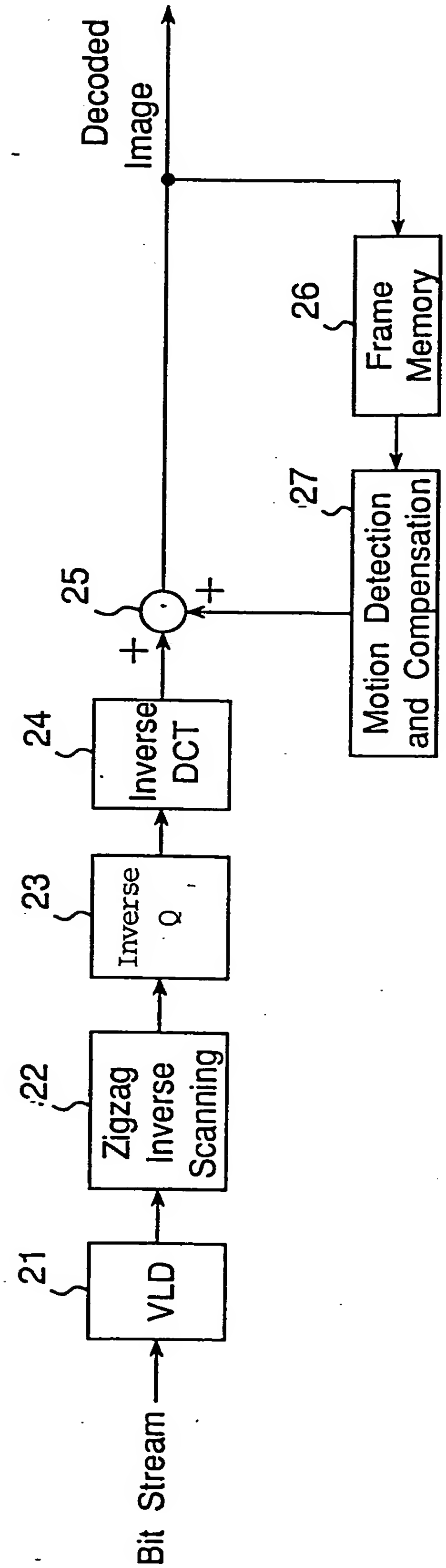
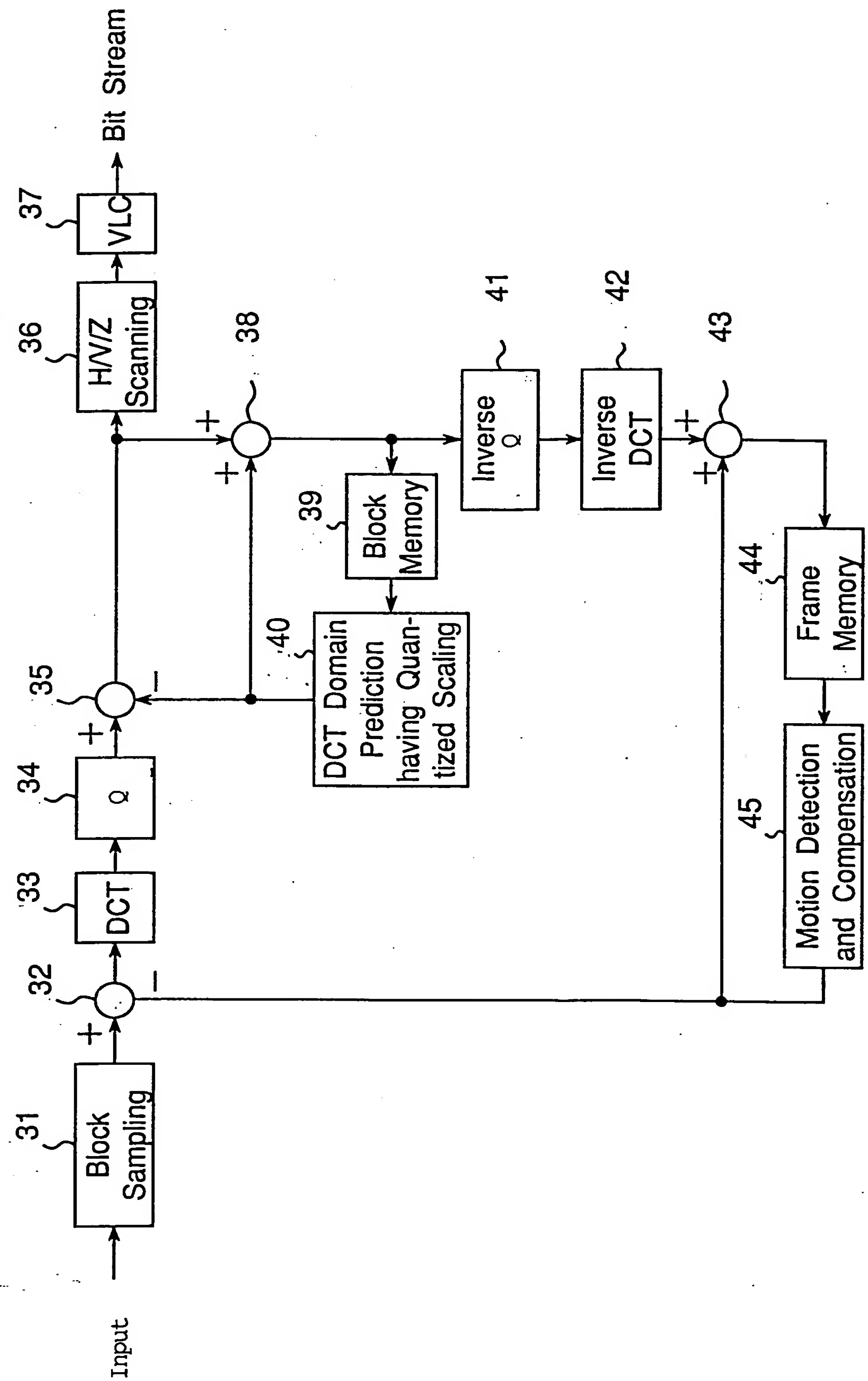

Bit Stream
21
VLD
22
Zigzag Inverse Scanning
23
Inverse Q
24
Inverse DCT
25
+
+
Decoded Image
26
Frame Memory
27
Motion Detection and Compensation

Fig. 3



Input
Block Sampling
31
32
DCT
33
Q
34
35
H/V/Z Scanning
36
VLC
37
Bit Stream
38
Block Memory
39
DCT Domain Prediction having Quantized Scaling
40
Inverse Q
41
Inverse DCT
42
43
Frame Memory
44
Motion Detection and Compensation
45

Fig. 4

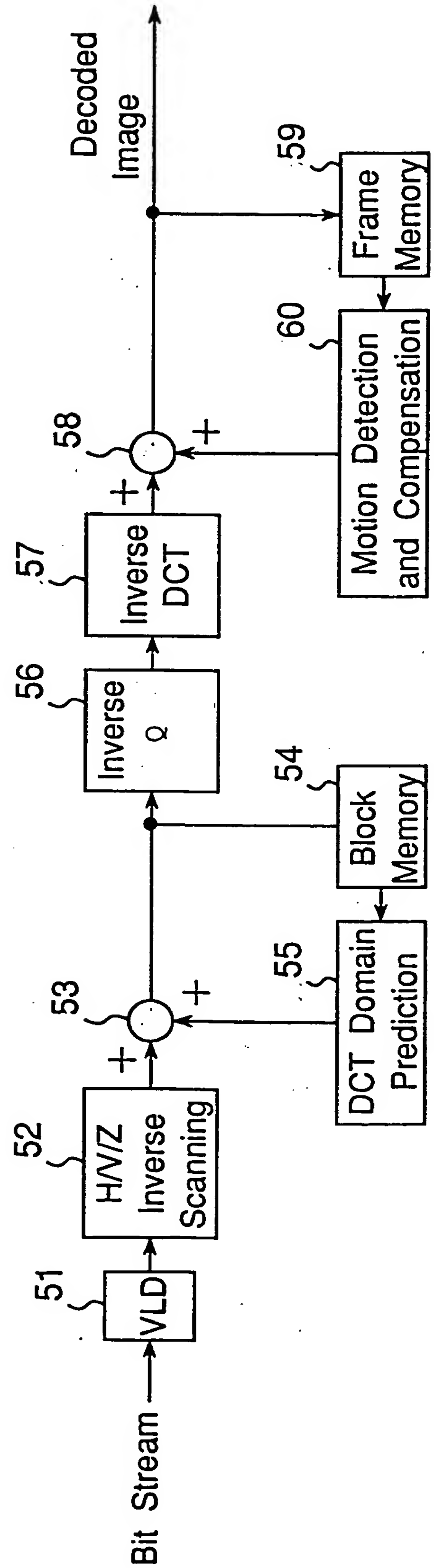

Bit Stream
51
VLD
52
H/V/Z Inverse Scanning
53
+
+
54
Block Memory
55
DCT Domain Prediction
56
Inverse Q
57
Inverse DCT
58
+
+
59
Frame Memory
60
Motion Detection and Compensation
Decoded Image

Fig. 5

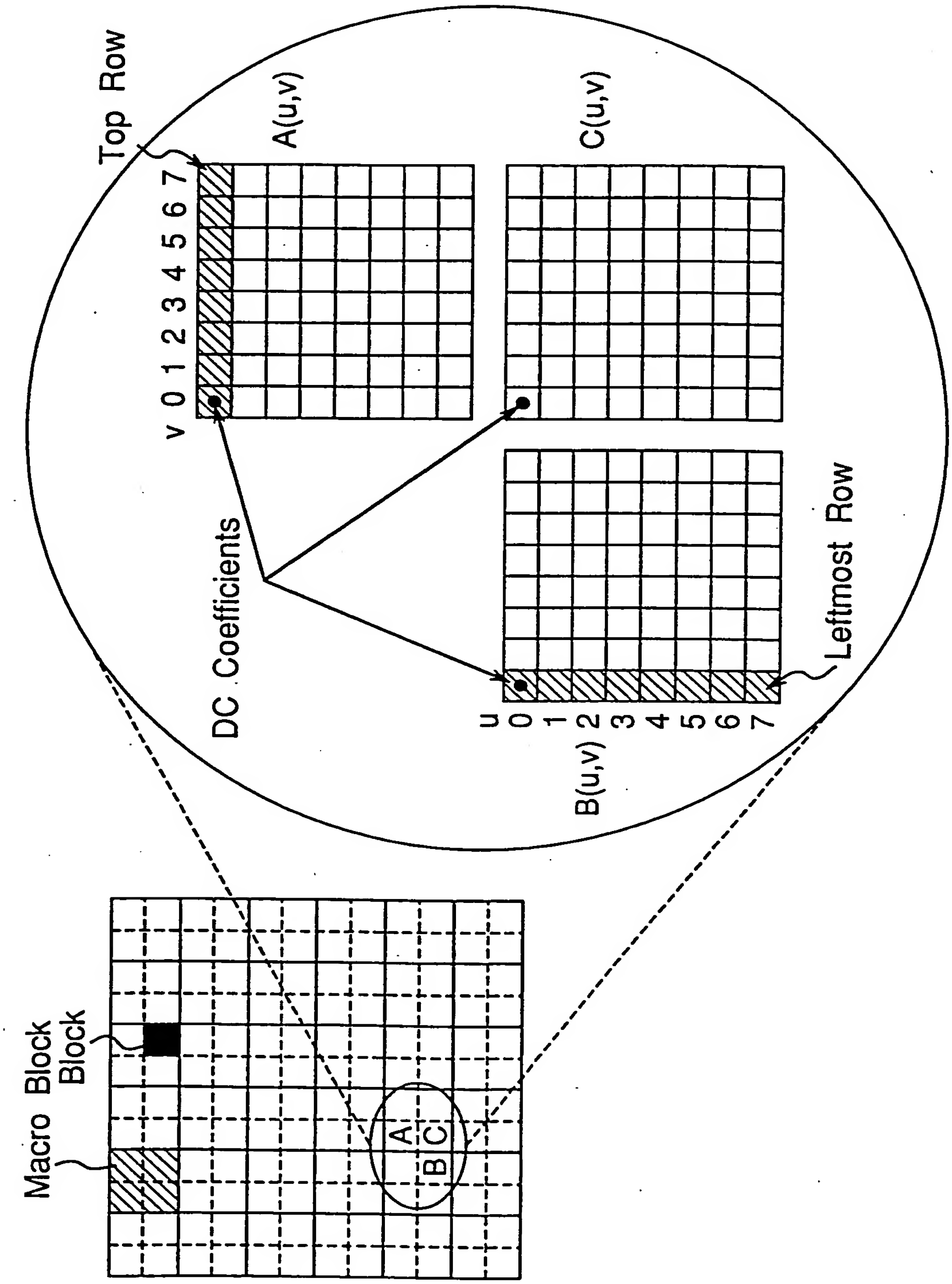

Top Row
A(u,v)
v 0 1 2 3 4 5 6 7
C(u,v)
DC Coefficients
Leftmost Row
B(u,v)
u 0 1 2 3 4 5 6 7
Macro Block
Block
A
B
C

Fig. 6

0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63

a) Horizontal Scanning

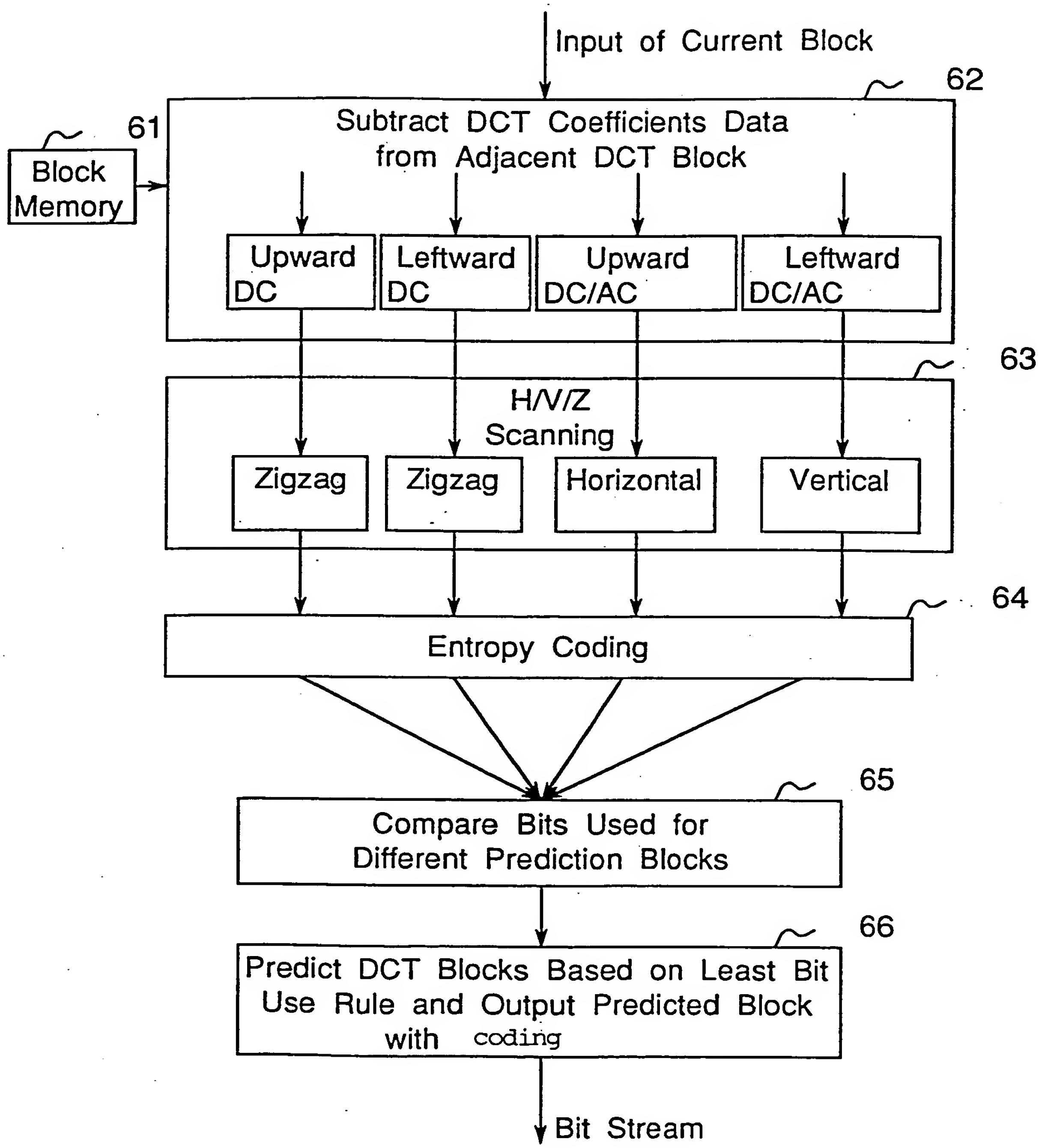
0	8	16	24	32	40	48	56
1	9	17	25	33	41	49	57
2	10	18	26	34	42	50	58
3	11	19	27	35	43	51	59
4	12	20	28	36	44	52	60
5	13	21	29	37	45	53	61
6	14	22	30	38	46	54	62
7	15	23	31	39	47	55	63

b) Vertical Scanning

0	1	5	6	14	15	27	28
2	4	7	13	16	26	29	42
3	8	12	17	25	30	41	43
9	11	18	24	31	40	44	53
10	19	23	32	39	45	52	54
20	22	33	38	46	51	55	60
21	34	37	47	50	56	59	61
35	36	48	49	57	58	62	63

c) Zigzag Scanning

Fig. 7


Input of Current Block
62
Subtract DCT Coefficients Data from Adjacent DCT Block
61
Block Memory
Upward DC
Leftward DC
Upward DC/AC
Leftward DC/AC
63
H/V/Z Scanning
Zigzag
Zigzag
Horizontal
Vertical
64
Entropy Coding
65
Compare Bits Used for Different Prediction Blocks
66
Predict DCT Blocks Based on Least Bit Use Rule and Output Predicted Block with coding
Bit Stream

Document Name: Abstract

Abstract:

(Object) Much effort has been made to remove all the existing redundancy in order to obtain a high efficiency for image coding. This includes the use of 8 × 8 DCT transform to reduce the spatial redundancy within the 8 × 8 block. Then, performing motion prediction and compensation is also included to reduce the temporary redundancy between frames. The invention has also discovered that other kinds of redundancies are present in the transform domain over an adjacent block.

(Solution) The redundancy can be removed or reduced to a large extent by using prediction from coefficients of a previously encoded adjacent block. The reduction in the redundancy can also be achieved by using an adaptive scan method in the entropy coding of a prediction error signal. The method of adaptively selecting an optimum prediction as well as a scan method are shown in embodiments. In order to reconstruct the original input image, a prediction code is transmitted to a decoder so that the decoder is enabled to perform a corresponding reverse operation.

Selected Figure: Fig. 3

Document Name: Official Correction Data

Corrected Document: Petition for Patent

<Approved or Supplemented Data>

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